DRAFT

63320 – 351 grams
63340 – 181 grams
Shadow Soils

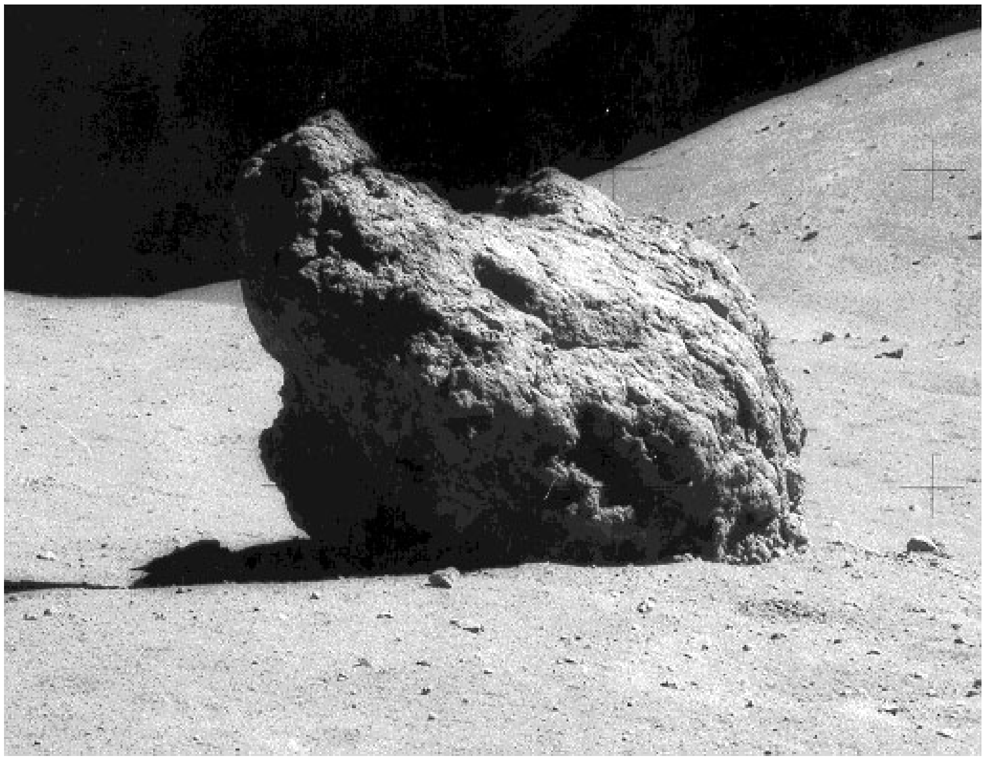


Figure 1: Shadow Rock at Apollo 16. AS16-106-17393. Rock is 5 meters across and 3 meters high.

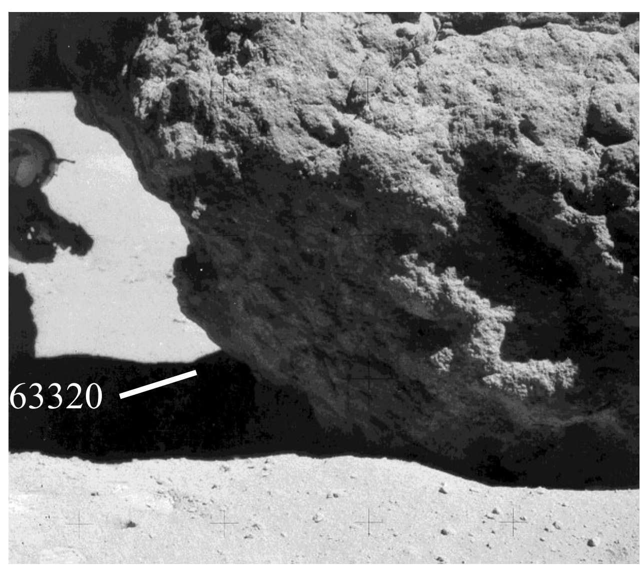


Figure 2: Shaded soil sample 63320 collected from "gopher hole" in shade. 63340 was collected from beneath 63320. AS16-160-17413.

Introduction

Apollo 16 soil samples 63320 and 63340 were collected from a "recess" far under the shadow cast by Shadow Rock (figures 1 and 2). However, Ulrich (1981) calculates that sunlight could have reached this area during the movement of the Sun across the sky. 63320 was collected from the surface and 63340 from underneath 63320 (Sutton 1981). A "companion soil" 63501 was collected from the unshaded regolith, 15 m southeast of Shadow Rock.

Shadow Rock is about 550 m south of the rim of North Ray Crater and the soils there are estimated to be about 50% young soil derived from North Ray Crater and 50% old soil (they have cosmic ray exposure ages of ~ 270 m.y.)

Eberhardt et al. (1976) found that ^{40}Ar and various volatile elements (In, Tl, Zn, Cd, Br and I) are enriched by about the same amount (~30-40%) in 63321 and 63341 compared with 63501. It is suggested that the shadowed area acted as a cold trap for volatiles in the lunar atmosphere.

Petrography

Horz et al. (1972) write *"a hole more than 1 m deep and approximately 50 cm wide was observed at the south end of Shadow Rock at station 13. Because of the shadowed condition, no precise surface photography is available, but the comments of the crew about the geometry of the "gopher hole" indicate that the soil materials were permanently shielded from the Sun. After the samples were received in the LRL, samples 63320 and 63340 were placed in specially sealed containers."*

63320 and 63340 are submature soils with Is/FeO values of 47 and 54 respectively (Morris 1978). Companion soil 63501 has Is/FeO = 46. Average grain size is 88 microns for 63321, 80 microns for 63341 and 70 microns for 63501. Heiken et al. (1973) and Houck (1982) determined the mineralogic mode of 63321 and 63341 and compared them with nearby reference soil 63501 (they look similar). Breccia samples 60017, 63335 and 63355 were chipped from the boulder.

Chemistry

The chemical compositions of the shadowed soils are given in tables 1 and 2 and figure 3 and 4. Eberhardt et al. (1976) compared the volatile element concentrations of 63321, 63341 and 63501 (figure 6).

Evensen et al. (1974) determined the composition of alkalis as a function of grain size.
Jovanovic and Reed (1973) determined halogens, Hg, Ru, Os and U for 63321, 63341 and 63501 finding nothing unusual about their concentrations. Wanke et al. (1975) also determined halogens for 63320, finding

Modal content of soils 63321, 63341 and ref. 63501 (90-150 micron).
From Houck 1982.

	63321	**63341**	63501 (ref.)
Agglutinates	31.4 %	32	40.9
Basalt	-	-	-
Breccia	46.9	43.9	39.9
Anorthosite	0.3	0.7	-
Norite	-	-	-
Gabbro	-	-	-
Plagioclase	12.2	15.7	15.1
Pyroxene	3.6	2	0.3
Olivine	-	0.3	0.7
Ilmenite	-		
Glass other	5.3	5.6	2.6

Modal content of soils 63321, 63341 Imamura et al. (1974) studied 54Mn
and ref. 63501 (90-150 micron).
From Heiken et al. 1973.

	63321	**63341**	63501 (ref.)
Agglutinates	32.6 %	40	44.6
Basalt	-	1.7	0.3
Breccia	42.5	35.5	36.3
Anorthosite	11.2	5.9	3
Norite	1.6	0.3	1.3
Gabbro	-	-	-
Plagioclase	9.6	12.6	10.3
Pyroxene	2.6	1.7	2
Olivine	-	-	-
Ilmenite	-		
Glass other	4.6	2	2.2

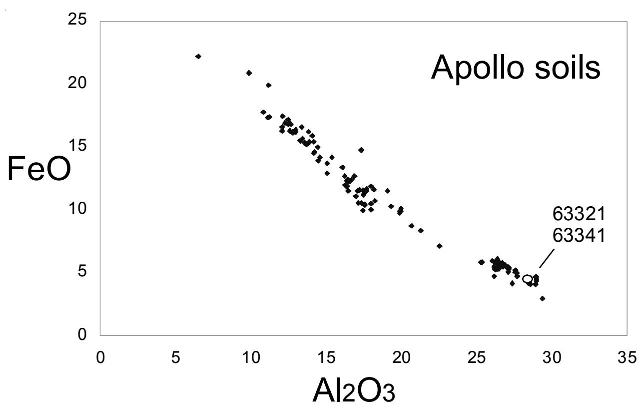


Figure 3: Samples 63321 and 63341 are among the most Al-rich lunar soils.

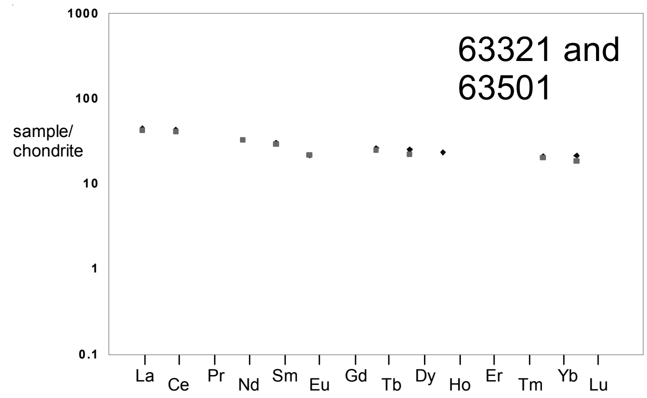


Figure 4: Normalized rare-earth-element diagram for 63321 and reference soil 63501 (data for both from Wanke et al. 1975).

them low in concentration. Muller (1973) and Kothari and Goel (1973) found nitrogen (~60 ppm) to be similar in all three samples. DesMarias et al. (1973) determined the carbon content (66 ppm) and Gibson and Moore (1973) found about 500 ppm sulfur (no more than elsewhere). The carbon content is relatively high (saturated?) for a submature soil (figure 5).

Cosmogenic isotopes and exposure ages

Eberhardt et al. (1976) determined the average cosmic ray exposure ages of 63321, 63241 and 63501 to be 260 m.y., 290 m.y. and 260 m.y. respectively using ^{78}Kr, ^{124}Xe and ^{126} Xe measurements. Fireman et al. (1973) determined the tritium content (^{3}H) of the shadowed soil 63321 (233 dpm/kg).

Imarura et al. (1974) determined the cosmic –ray induced activity of ^{53}Mn = 359 dpm/kg. The high ^{53}Mn activity could be due to lateral transport of freshly irradiated material under the boulder, or Shadow Rock may have been emplaced in its present location a short time ago (the half-life of ^{53}Mn is 3.7 m.y.).

Other Studies

Kirsten et al. (1973) and Bogard and Nyquist (1973) reported the rare gas composition of shaded soils 63321 and 63341, but didn't find anything unusual with respect to other soils. However, Eberhardt et al. (1976) discovered an enrichment of ^{40}Ar of 38% for 63321 and 28% for 63341 relative to 63501 (figure 6). They found that the geometry of the shadowed area is such that reaccelerated lunar atmosphere ions, such as ^{40}Ar, can reach the soil, whereas the solar wind is effectively shielded.

Holmes et al. (1973) and Gammage and Holmes (1975) studied the influence of water vapor and liquid water on various adsorption isotherms for 63341 (figure 7).

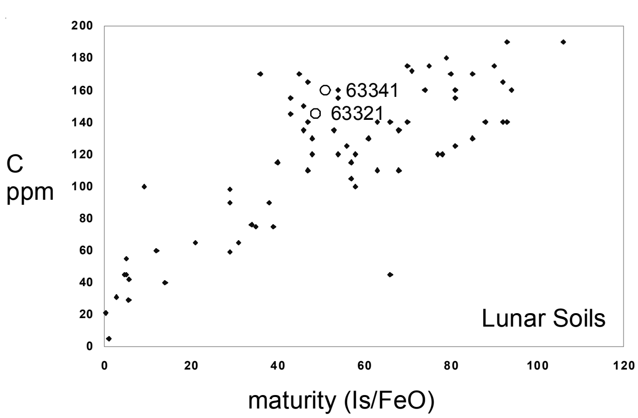


Figure 5: Samples 63321 and 63341 have relatively high carbon content (saturated?).

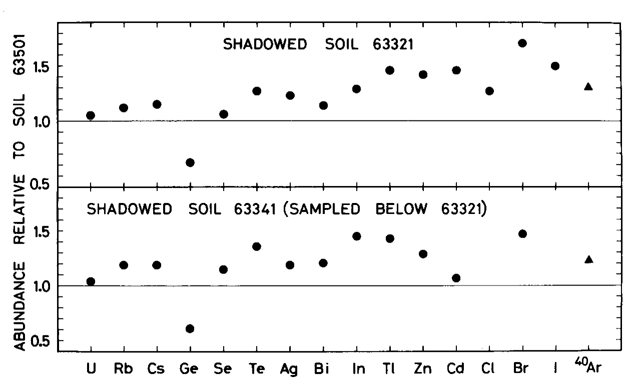


Figure 6: Volatile elements are enrich by about the same factor as 40Ar in the shadowed soils 63320 and 63240 when compared with soil 63501 (from Eberhardt et al. 1976).

Table 3	U ppm	Th ppm	K ppm	technique
Eldridge et al. 1975				
63321	0.39	1.35	800	radiation
63341	0.4	1.33	790	counting
63501	0.41	1.53	728	

Cadenhead et al. (1977) found the surface area of 63221 and 63241 to be as expected for samples of that maturity.

Processing

Sad to say, these shadowed soils were not returned in a sealed container. They were only protected from humid spacecraft cabin air and Pacific atmosphere by the Teflon bags that they were collected in, surrounded by layers of porous beta cloth (Teflon-coated, woven, fiberglass). They would have experienced several cycles of depressurization – repressurization in the LM, one in the CM. They were sealing in Pacific air during transfer to the LRL. Finally they were exposed to the residual moisture of the "dry" N_2 glove boxes during preliminary examination.

However, only a small part of 61221 was sieved and a large portion has apparently been kept in the original Teflon collection bag (DB). In 1979, a portion was split off to go into remote storage (RSF), again exposing the sample to "dry" N2 cabinet air in the new curation facility (N_2 cabinet air has variously 10-50 ppm H_2O).

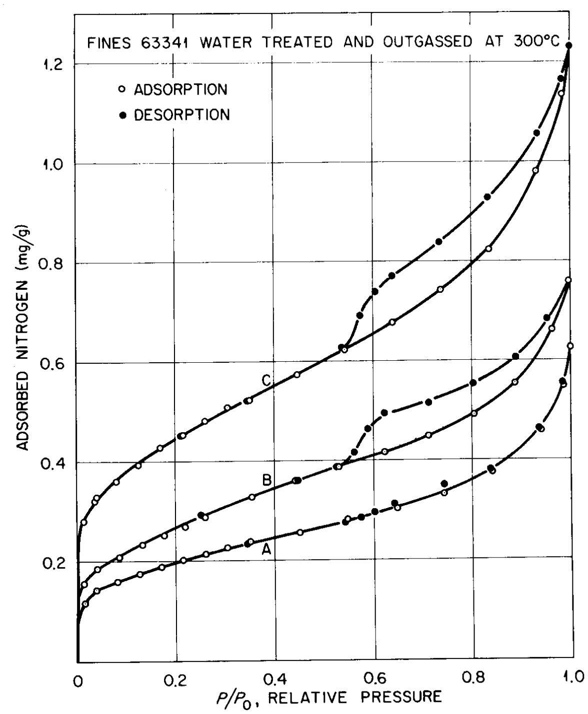
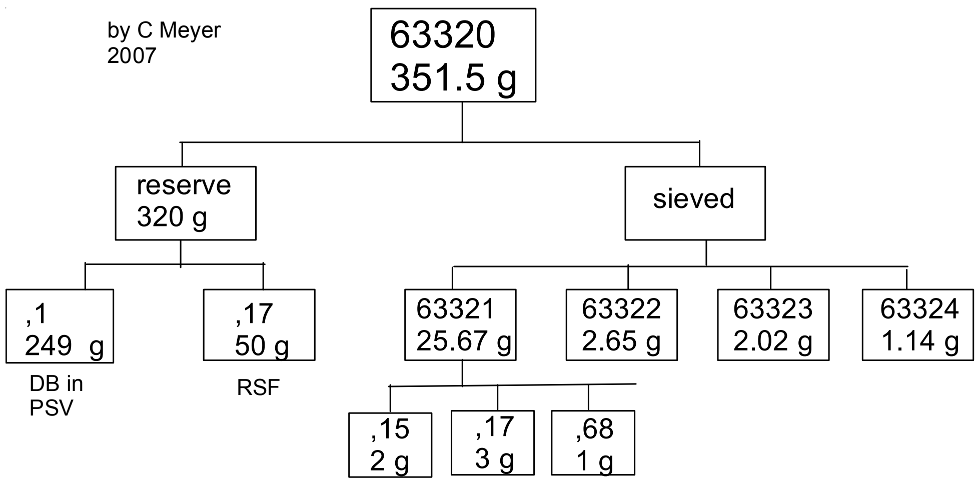


Figure 7: Adsorption isotherms of N2 for fines from 63341 (Gammage and Holmes 1975).


by C Meyer
2007
63320
351.5 g
reserve
320 g
sieved
,1
249 g
DB in
PSV
,17
50 g
RSF
63321
25.67 g
63322
2.65 g
63323
2.02 g
63324
1.14 g
,15
2 g
,17
3 g
,68
1 g

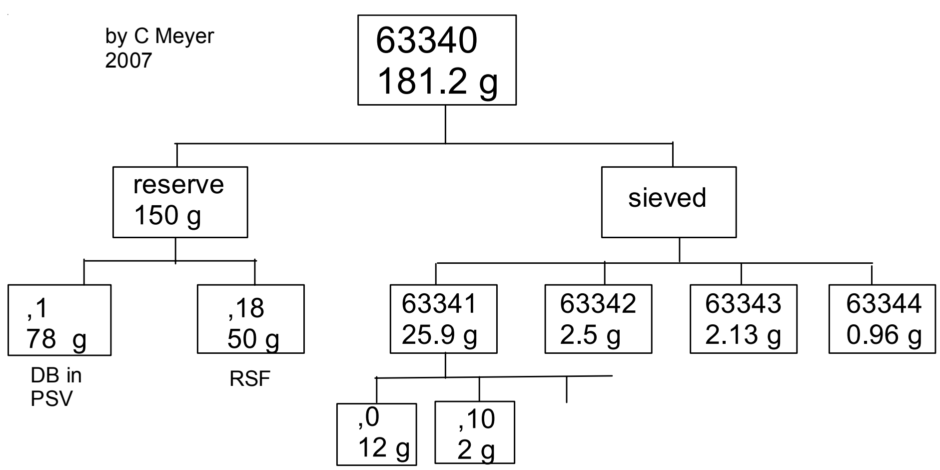

by C Meyer
2007
63340
181.2 g
reserve
150 g
sieved
,1
78 g
DB in
PSV
,18
50 g
RSF
63341
25.9 g
63342
2.5 g
63343
2.13 g
63344
0.96 g
,0
12 g
,10
2 g

Table 1. Chemical composition of 63321.

reference	Brunfeldt73		Philpotts73		Krahenbuhl73		Boynton76			Evensen73		Muller75		Nyquist76		Wanke75	
weight	63321						63320										
SiO2 %																44.93	
TiO2	0.35	(a)					0.65	0.58	(a)							0.53	
Al2O3	28.9	(a)					28.1	25.2	(a)			26.5	(d)			27.6	
FeO	4.7	(a)					4.76	4.63	(a)			4.8	(d)			4.73	
MnO	0.068	(a)					0.065	0.067	(a)							0.063	
MgO	6.93	(a)					5.8	5.97	(a)			5.7	(d)			5.29	
CaO	15.67	(a)					15.4	16.5	(a)			16.23	(d)			15.7	
Na2O	0.57	(a)					0.49	0.52	(a)			0.58	(d)			0.53	
K2O	0.077	(a)	0.096	(c)						0.11	(c)	0.106	(e)			0.1	
P2O5																0.09	(f)
S %																0.05	(f)
sum																	
Sc ppm	8.03	(a)					8.2	8.5	(a)							8.53	(a)
V	46	(a)					15	21	(a)								
Cr	642	(a)					660	666	(a)								
Co	23.5	(a)					19.7	19.8	(a)							22.5	(a)
Ni	311	(a)					244	250	(a)							330	(a)
Cu	9.3	(a)															
Zn	23	(a)			17	(b)	16.4	17	(b)								
Ga	5.5	(a)					5	5.6	(b)								
Ge ppb					404	(b)	510	540	(b)								
As																	
Se					199	(b)											
Rb	2.3	(a)	2.18	(c)	1.8	(b)				2.29	(c)	2.2	(e)	1.72	(c)		
Sr	170	(a)	179	(c)						181	(c)	172	(e)	191	(c)	198	(a)
Y																	
Zr																	
Nb																	
Mo																	
Ru								16	(b)								
Rh																	
Pd ppb																	
Ag ppb					7.9	(b)											
Cd ppb					78	(b)	102	93	(b)								
In ppb	40	(a)					9.6	10.5	(b)								
Sn ppb																	
Sb ppb					1.23	(b)											
Te ppb					17.3	(b)											
Cs ppm	0.2	(a)			0.083	(b)						0.1	(e)			0.1	(a)
Ba	147	(a)					120	130	(a)	116	(c)	113	(e)			115	(a)
La	10.8	(a)					10.6	9.3	(a)			9	(e)			10.5	(a)
Ce	24.8	(a)					26	24	(a)							26.2	(a)
Pr																	
Nd																	
Sm	4.56	(a)					4.6	4.1	(a)							4.49	(a)
Eu	1.35	(a)					1.15	1.21	(a)							1.21	(a)
Gd																	
Tb	0.88	(a)					1	0.78	(a)							0.96	(a)
Dy	4.88	(a)					5.4	5.9	(a)							6.12	(a)
Ho	1.4	(a)														1.3	(a)
Er																	
Tm																	
Yb	3.98	(a)					3.3	3.1	(a)							3.4	(a)
Lu	0.56	(a)					0.44	0.45	(a)							0.52	(a)
Hf	4.8	(a)					2.8	3.3	(a)							3.95	(a)
Ta	0.54	(a)					0.4	0.5	(a)							0.44	(a)
W ppb																	
Re ppb					0.669	(b)											
Os ppb																	
Ir ppb					8.29	(b)	6.5	5	(b)							10	
Pt ppb																	
Au ppb					8.6	(b)	4.4	3.8	(b)					Silver73			
Th ppm	1.2	(a)					1.6	1.3	(a)					1.726	(c)	1.35	(a)
U ppm	0.5	(a)			0.401	(b)	0.55	0.44	(a)			0.59	(e)	0.477	(c)		

technique: (a) INAA, (b) RNAA, (c) IDMS, (d) AA, (e) NA, (f) XRF

Table 2. Chemical composition of 63340.

reference	Brunfeldt73		Philpotts73		Korotev81	Krahenbuhl73		Evensen73		Silver73	
weight	63341				unpublished						
SiO2 %											
TiO2	0.6	(a)									
Al2O3	29	(a)									
FeO	4.53	(a)									
MnO	0.067	(a)									
MgO	7.3	(a)									
CaO	12.45	(a)									
Na2O	0.57	(a)									
K2O	0.147	(a)	0.107	(c)				0.097	(c)		
P2O5											
S %											
sum											
Sc ppm	7.95	(a)									
V	34	(a)									
Cr	650	(a)									
Co	19.5	(a)									
Ni	345	(a)									
Cu	8.3	(a)									
Zn	17	(a)				15.5	(b)				
Ga	5.2	(a)									
Ge ppb						400	(b)				
As											
Se						216	(b)				
Rb	1.7	(a)	2.49	(c)		1.9	(b)	2.05	(c)		
Sr	140	(a)	181	(c)				180	(c)		
Y											
Zr											
Nb											
Mo											
Ru											
Rh											
Pd ppb											
Ag ppb						7.6	(b)				
Cd ppb						57.5	(b)				
In ppb	45	(a)									
Sn ppb											
Sb ppb						1.23	(b)				
Te ppb						18.5	(b)				
Cs ppm	0.05	(a)				0.086	(b)				
Ba	92	(a)						97.5	(c)		
La	11.2	(a)									
Ce	25.2	(a)									
Pr											
Nd											
Sm	4.45	(a)									
Eu	1.42	(a)									
Gd											
Tb	0.93	(a)									
Dy	6.18	(a)									
Ho	1.5	(a)									
Er											
Tm											
Yb	3.87	(a)									
Lu	0.56	(a)									
Hf	3.5	(a)									
Ta	0.45	(a)									
W ppb											
Re ppb						0.741	(b)				
Os ppb											
Ir ppb						11.1	(b)				
Pt ppb											
Au ppb						7.08	(b)				
Th ppm	1	(a)								1.8	(c)
U ppm	0.4	(a)				0.398	(b)			0.617	(c)

technique: (a) INAA, (b) RNAA, (c) IDMS

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